COOPERATIVE ROBOTICS AND THE SEARCH FOR EXTRATERRESTRIAL LIFE.

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Introduction: If we think tenuous abodes of life may be hiding in remote extraterrestrial environmental niches, and if we want to assess the biological status of a given locale or entire planet before sending humans (perhaps because of contamination concerns or other motivations) then we face the challenge of robotically exploring a large space efficiently and in enough detail to have confidence in our assessment of the biological status of the environment in question. On our present schedule of perhaps two or so missions per opportunity, we will likely need a different exploratory approach than singular stationary landers or singular rover missions or sample return, because there appear to be fundamental limitations in these mission profiles to obtain the many samples we will likely need if we want to have confidence in assessing the biological status of an environment in which life could be hiding in remote environmental niches. Singular rover missions can potentially accommodate sampling over a fairly large area, but are still limited by range and can be a single point of failure. More importantly, such mission profiles have limited payload capabilities which are unlikely to meet the demanding requirements of life-detection. Sample return has the advantage of allowing sophisticated analysis of the sample, but also has the severe limitations associated with only being able to bring back a few samples.

This presentation will suggest two cooperative robotic approaches for exploration that have the potential to overcome these difficulties and facilitate efficient and thorough life-detecting exploration of a large space. Given the two premises state above, it appears at least two fundamental challenges have to be met simultaneously: coverage of a large space and bringing to bear a sophisticated suite of detection and experimental payloads on any specific location in order to address a major challenge in looking for extraterrestrial life: namely, executing a wide variety of detection scenarios and in situ experiments in order to gather the required data for a confident assessment that life has been detected and to, more generally, cover a wide range of extraterrestrial life possibilities. Cooperative robotics lends itself to this kind of problem because cooperation among the combined capabilities of a variety of simple single function agents can give rise to fairly complex task execution such as the search for and detection of extraterrestrial life.

Shot-Gun Cooperative Robotics: Specifically, a kind of *cooperative robotics shot-gun approach* [1] in the form of tens to hundreds or more small robots, each with a singular life-detection related capability such as detection of water and organics (perhaps even nucleic acids, amino acids and associated chirality, etc.) or such as metabolism measurement experiments, epiflourescence microscopy, molecular sequencing, culturing, sub-surface boring payloads, imaging capabilities, etc. could cover much area and work together by communicating results to the rest of the "swarm" which could then focus on a particular location where a positive result was found.

Mission Scenario Example: An over-simplified search and detection scenario might be something like: first send many small water detection robots, including subsurface boring moles, to a promising area. If water is detected by any one robot, confirm with another robot, and signal to other robots (which could be stored nearby or in orbit, or already deployed nearby, etc.) that have the functionality for the next step which might be detection and measurement of organics. If a promising result is reported, perhaps a metabolism based experiment would be required next, followed by an imaging based robot, and then perhaps more sophisticated functionality such as molecular sequencing or culturing.

In general, this approach can been seen as a kind of biologically inspired exploration methodology, perhaps a form of "swarm intelligence" [2]. The benefit of this kind of approach is that large areas can be covered with diverse detection and experimental techniques which increase the chance of detecting life, and comprehensive data can be obtained in an efficient manner during just one mission opportunity.

. **Cooperative Family Robotics:** A second form of cooperative robotics might be characterized as *cooperative family robotics* where a larger parent rover carries smaller rovers with additional specialized functionality to be deployed as required by the higher level analysis of the more mobile larger rover. A system like this could be large or small. If a larger size were feasible, we'd want to consider the possibility of developing a walk-roll and maybe even hop capability perhaps by designing lockable wheels that can act as feet for walking (e.g. to navigating difficult terrain) and allow for crouching and perhaps hopping, as well as covering large distances by unlocking the wheels for rolling. The primary advantages of this approach are that specialized functions can be selectively deployed in real-time and that the parent rover can act as a central coordinating agent as well as an infrastructural support element for power recharging of the smaller rovers and more sophisticated forms of navigation, drilling, communication, etc.

References:

[1] Lupisella M. L. (1998) "Life" Looking for Life, *Jet Propulsion Laboratory Biomorphic Explorer Workshop*. [2] Bonabeau E., Dorigo M., Theraulaz G. (1999) Swarm intelligence: from natural to artificial systems. New York: Oxford University Press.